Soil pH Protocol

Purpose

To measure the pH of a soil horizon

Overview

Students mix dried and sieved soil samples with distilled water. The mixture is allowed to settle until a relatively clear layer is formed. Students use a pH pen, pH meter, or pH paper to determine the pH of the sample. The procedure is done three times for each horizon.

Student Outcomes

Students will be able to apply laboratory tests for pH to soil samples. Students will be able to relate pH to the physical and chemical properties of a soil sample.

Science Concepts

Earth and Space Sciences

Soils have properties including color, texture structure, and density; they support the growth of many types of plants and serve numerous other functions in the ecosystem.

The surface of the Earth changes.

Water circulates through soil affecting its properties.

Physical Sciences

Objects have observable properties.

Chemical reactions take place in every part of the environment.

Scientific Inquiry Abilities

Identify answerable questions.

Design and conduct an investigation.

Use appropriate mathematics to analyze data.

Develop descriptions and explanations using evidence.

Communicate procedures and explanations.

Time

One 45-minute class period

Level

All

Frequency

Once for each soil horizon

Materials and Tools

Oven-dried, sieved soil
Distilled water
Pencil or pen
100-mL graduated cylinder
Glass stirring rod or other stirring device
100 mL beaker
pH meter, pH pen, or pH paper
Balance (accurate to 0.1 g)
Soil pH Data Sheet

Preparation

Collect required soil samples.

Dry and sieve soil samples, and store them in a sealed container.

Calibrate the balance to 0.1 g.

Calibrate the pH pen or meter. (See procedure for calibration in *the pH Protocol* in the *Hydrology Investigation*.)
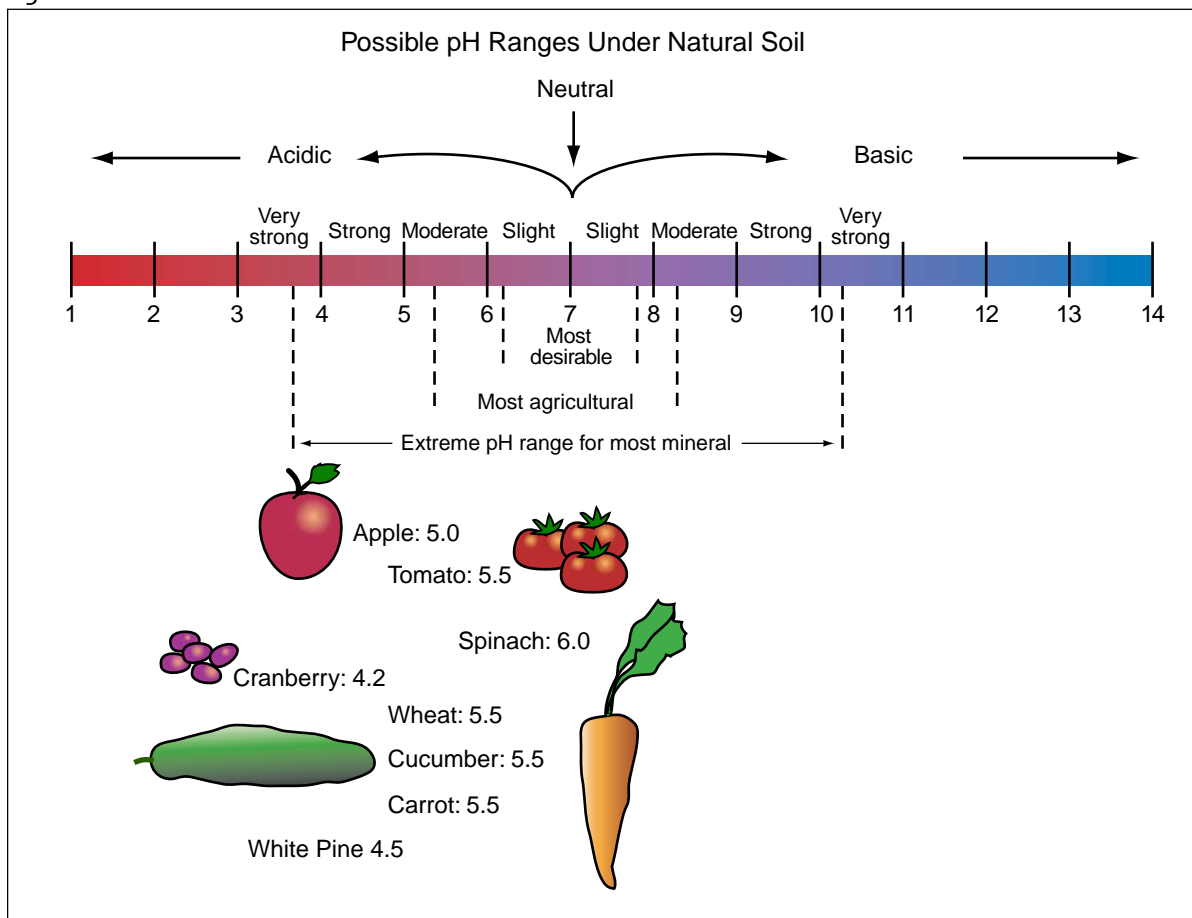
Prerequisites

Soil Characterization Protocol

Soil pH Protocol – Introduction

The concentration of hydrogen ions is an important consideration when studying soil. As in the study of hydrology, the pH scale is used as an indication of the concentration of hydrogen ions in the soil. Dry, sieved soil is dissolved in a specified volume of water with a known pH. The extent to which the dissolved soil changes the pH of the water is an indicator of the number of hydrogen ions contained in the soil. pH is measured on a logarithmic scale and represents the negative logarithm of the hydrogen ion concentration in moles/L. For example, a pH of 2 represents a concentration of 1×10^{-2} moles/L (0.01) hydrogen ions, and pH 8 represents a concentration of 1×10^{-8} moles/L (0.00000001) hydrogen ions.

When the soil contains a high concentration of hydrogen ions, it is considered to be *acidic* and when it has a low number of hydrogen ions, it is considered to be *basic*. pH 7 is considered to be "neutral" (neither acidic nor basic). The pH scale ranges from 1-14 with pH 1 being extremely acidic (1×10^{-1} or 0.1 moles of hydrogen ions per liter), and pH 14 being extremely basic (1×10^{-14} moles of hydrogen ions per liter or 0.00000000000001 moles/L).

Soil pH is an indication of the soil's chemistry and fertility. The pH affects the chemical activity of the elements in the soil, as well as many of the soil properties. Different plants grow best at different pH values. See Figure SO-PH-1. Farmers and gardeners may add materials to their soil to change its pH depending upon the type of plants they want to grow. The pH of the soil may also affect the pH of ground water or of a nearby water body such as a stream or lake.

Figure SO-PH-1

Possible pH Ranges Under Natural Soil

Neutral

Acidic — Basic

Very strong | Strong | Moderate | Slight | Slight | Moderate | Strong | Very strong

1 2 3 4 5 6 7 8 9 10 11 12 13 14

Most desirable

Most agricultural

Extreme pH range for most mineral

Apple: 5.0
Tomato: 5.5
Spinach: 6.0
Cranberry: 4.2
Wheat: 5.5
Cucumber: 5.5
Carrot: 5.5
White Pine 4.5

The pH of soil controls many of the chemical and biological activities that take place in the soil and also indicates something about the climate, vegetation, and hydrologic conditions under which the soil formed. The pH of a soil horizon (how acidic or basic the soil is) is affected by the parent material, the chemical nature of the rain and other water entering the soil, land management practices, and the activities of organisms (plants, animals, and microorganisms) living in the soil. For example, needles from pine trees are high in acids, and as they decay over time, they lower the pH of moist soils.

Teacher Support

Preparation

Have students practice using the pH equipment by testing the pH of different liquids at different pH levels.

Measurement Procedures

To measure pH, students mix dry soil samples with distilled water until the soil and liquid are in equilibrium and provide an accurate measurement of the soil pH. A 1:1 soil/water solution is used for this protocol because it is similar to a standard method for professional soil pH measurements. The distilled water used in this protocol may or may not have a pH of 7 depending on the purity of the water and how long it has been exposed to the atmosphere. It is important that students report the pH of the distilled water on their *Soil pH Data Sheets* so that scientists are able to determine whether the distilled water has affected their pH measurements.

Managing Materials

While performing their soil pH measurements, students should be sure that the pH meter is working properly. They should calibrate it and, if necessary, replace weak or dead batteries.

For some soil samples, especially those high in clay, the soil in the water will not settle after mixing and will not form a supernatant. In this case, after thorough mixing according to the

protocol, place the pH meter or paper into the top of the soil/liquid suspension and take a reading.

Managing Students

If a single team of students is measuring all three samples of a horizon, have them process the samples in parallel, not in sequence. This will allow the protocol to be completed in less than 45 minutes.

Questions for Further Investigation

What natural changes could alter the pH of a horizon?

How does the pH of the rain affect the pH of a soil horizon?

How does the pH of the soil affect the pH of local water bodies?

How does climate affect the pH of a horizon?

How do slope and aspect affect the pH of a horizon?

How does the type of vegetation growing on the soil affect the pH of the soil?

Soil pH Protocol
Lab Guide

Task

To obtain three pH readings for a soil horizon

What You Need

❏ Dried sieved soil

❏ Distilled water

❏ 100-mL graduated cylinder

❏ Four 100-mL containers

❏ Balance (accurate to 0.1 g)

❏ *pH Data Sheet*

❏ Pencil or pen

❏ Glass stirring rod or other stirring device

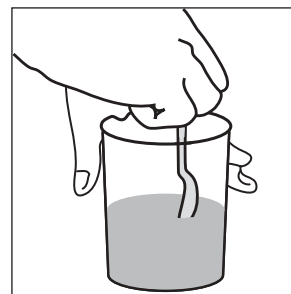❏ pH meter or pH paper

In the Lab

1. In a cup or beaker, measure the pH of the distilled water you will be using. Dip the pH paper or calibrated meter into the water and obtain a reading. Record this on your *pH Data Sheet*
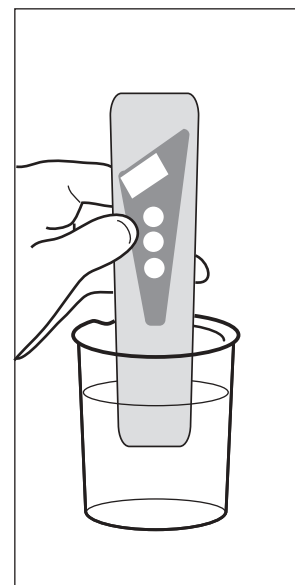
2. In a cup or beaker, mix 40 g of dried and sieved soil with 40 mL of distilled water (or other amount in a 1:1 soil to water ratio) using a spoon or other utensil to transfer the soil.
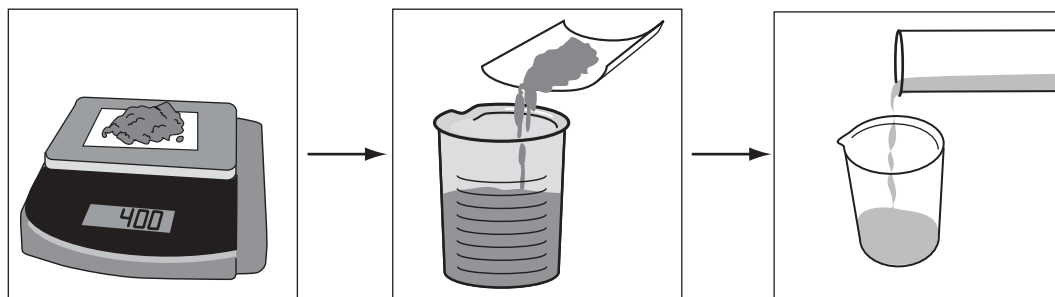
3. Stir the soil/water mixture with a spoon or other stirrer until it is thoroughly mixed. Stir the soil/water mixture for 30 seconds and then wait for three minutes for a total of five stirring/waiting cycles. Then, allow the mixture to settle until a supernatant (clearer liquid above the settled soil) forms (about 5 minutes).

4. Measure the pH of the supernatant using the pH paper or meter. Dip the pH paper or calibrated pH meter in the supernatant. Record the pH value on the *Soil pH Data Sheet*.

5. Repeat steps 2-4 for two more samples from the same horizon.
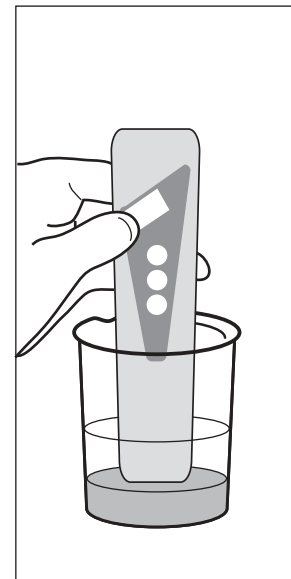
Soil pH Protocol–Looking at the Data

Are the data reasonable?

A soil's parent material, the climate under which it formed, the vegetation it supports and the amount of time it has had to develop, determines its pH. In general, soil pH values range from 4.0 for acidic, organic rich soils, to 8.5 for soils with a high number of free carbonates. Occasionally, the pH can go as low as 3.5 or as high as 10.

Generally, the pH will not vary much from horizon to horizon in a soil profile. This is because the pH scale is a base 10 logarithmic scale, so the differences of one in pH mean there are 10 times more hydrogen ions, or 10 times more acidity. In some cases, there might be a drastic change in parent material causing a very different pH between horizons. For example, materials may be deposited onto a horizon or some human intervention has occurred such as addition of limestone. Drastic changes in soil pH between soil horizons may help students to uncover clues about the story of the soil at that location. Students should expect some change from the top to the bottom of the profile, depending on the amount of organic matter, free carbonates, and weathering of the soil. If there is a lot of organic matter at the surface, and no limestone has been added, the pH in the upper horizons may be lower than those below. Where carbonates are present, horizons tend to have high pH values.

What do scientists look for in the data?

Many different scientists are interested in soil pH data. Soil pH measurements, in combination with soil characterization measurements and other GLOBE measurements, provide scientists a great deal of information about the environment. For example, soil pH helps scientists understand the chemical properties of the soil and the potential for certain nutrients to be stored or released. With this information, scientists determine the suitability of a soil for plant growth.

Scientists also predict the movement of materials into the hydrologic system. They consider rainfall chemistry when they make predictions of changes in soil chemistry and soil pH over time.

Soil pH helps scientists to reconstruct the development of a soil and predict the nature of the soil in the future.

An Example of a Student Research Project

Middle school students from Keflavik, Iceland collected soil samples while carrying out soil characterization measurements on a soil pit. They dried and sieved three samples for each horizon in their sample site and performed the *Soil pH Protocol* on each sample.

In order to analyze their data, they decided to graph the pH measurements they collected. The graph plotted the pH measurements for each horizon at the mid-point depth of each soil horizon. The students calculated the mid-point depth according to the following equation:

$$(\text{Bottom Depth} - \text{Top Depth})/2 + \text{Top Depth}$$

Horizon 1: (10-0)/2 +0 = 5.0 cm

Horizon 2: (23-10)/2 +10 = 16.5 cm

Horizon 3: (44-23)/2 + 23 = 33.5 cm
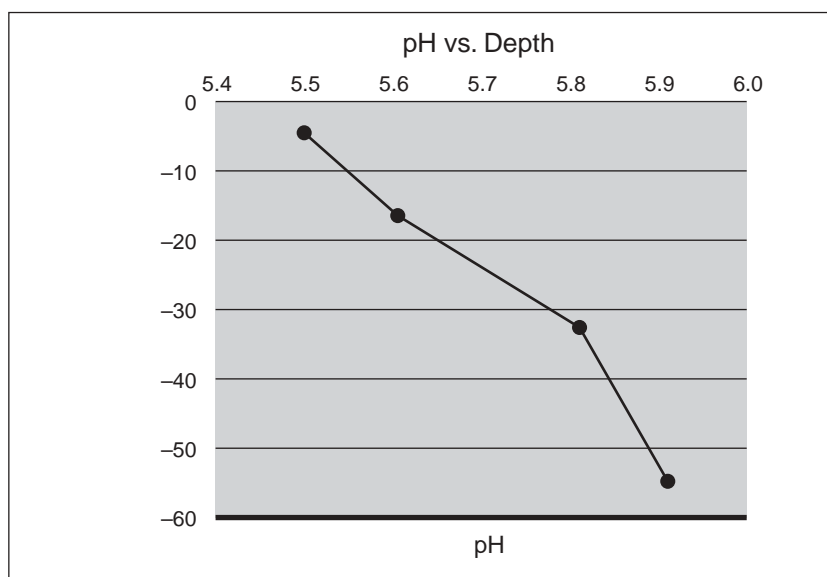
Horizon 4: (65-44)/2 + 44 = 54.5 cm

The results of their measurements are in the table below.

Horizon	Top Depth	Bottom Depth	Mid-Point Depth	pH (mean of 3 replicates)
1	0.0	10.0	5.0	5.5
2	10.0	23.0	16.5	5.6
3	23.0	44.0	33.5	5.8
4	44.0	65.0	54.5	5.9

Using the data in the table, the students plotted the mean pH at the mid-point depth of each horizon as shown in the graph below.

The students noticed that the pH was lowest at the top of the soil profile and increased with depth. They hypothesized that weathering of the soil at the surface and inputs of rain or organic matter caused the low pH at the top of the profile.

The students were interested in knowing whether the trend in pH they observed was typical of soils in other parts of the world with different climates and vegetation. According to the MUC classification guide, the land cover type at their site was dwarf-shrub/moss tundra. They used the GLOBE data archive to search for other schools that had made soil pH measurements, and found two schools in areas different from their own.

One school was a secondary School in Deir Allah, Jordan. The students at this school reported their vegetation type as row crop or pasture. The pH data reported by this school are given in the table below.

Deir Allah, Jordan

| Horizon	Top Depth	Bottom Depth	Mid-Point Depth	pH (mean of 3 replicates)
1	0.0	20.0	10.0	8.0
2	20.0	33.0	26.5	8.2
3	33.0	44.0	38.5	8.5
4	44.0	100.0	72.0	8.5

The other school they chose was a middle school in New York, USA. The students at this school reported their vegetation type as evergreen-needled trees. The pH data reported by this school are given in the table below.

New York, USA

Horizon	Top Depth	Bottom Depth	Mid-Point Depth	pH (mean of 3 replicates)
1	0.0	13.0	6.5	2.9
2	13.0	23.0	18.0	3.4
3	23.0	35.0	29.0	3.4
4	44.0	60.0	52.0	4.0

The students then plotted the pH values at the midpoints for each of the three schools on one graph as shown below.
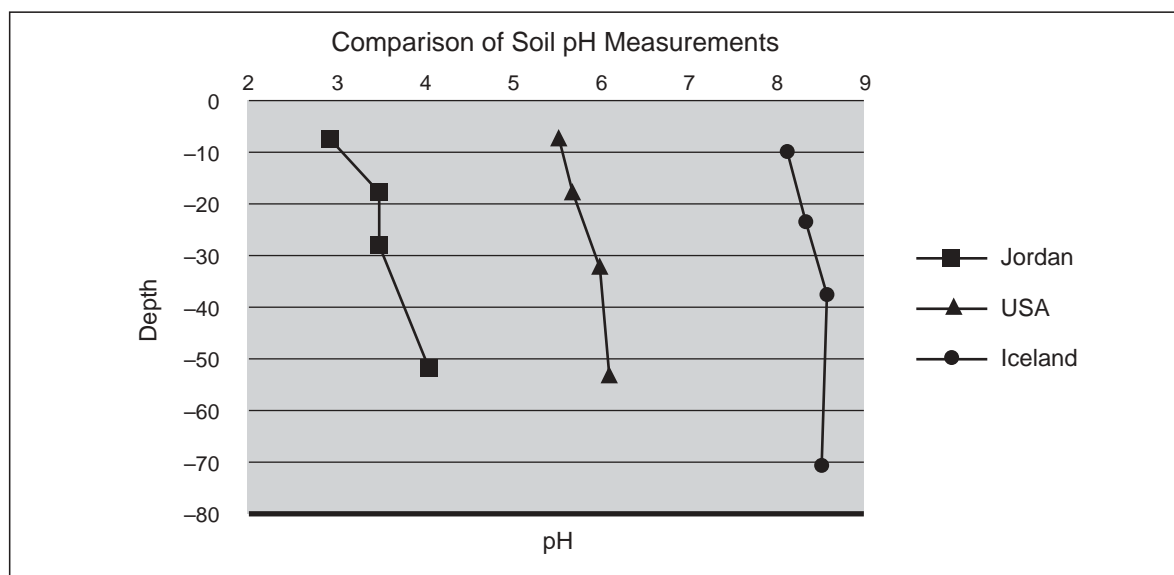
The students noticed considerable differences in the pH values at each of these locations. The soil in Jordan had much higher pH values than the soil in Iceland, while the New York school had much lower pH values. They noticed a trend of increasing pH with increasing depth at all three of schools. The students concluded that deeper soils have a higher pH in many different kinds of soils.

The students realized that more information about each location would help to better understand the pH differences at the sites. At a future date, they decided they would contact students at each school using GLOBE mail to find out more about their locations. They also planned to download precipitation and temperature data to see whether the differences in the amount and pH of annual rainfall and mean annual temperature at these schools would give an indication of why the pH values were so different.